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The Importance of Public Awareness During a Trap-Neuter-Release Program

If a conservationist were to be told that a single species was responsible for the global extinction of 40 types of birds (Doherty et al. 2016), he or she would most likely organize a mob search. Adding an additional 6.9-20.7 billion mammal deaths per year in the United States alone, this species is no doubt a skilled hunter (Feral cats…2013). Upon learning this, the conservationist mob would begin to sharpen their pitchforks and ignite their torches. And with estimated U.S. populations between 148 to 188 million individuals (Feral cats…2013), the species is showing no overall signs of decline, therefore finding these beasts cannot be too difficult, right? Turns out, in order for this mob to have their first sighting of these mystery creatures, they may not even have to leave their own homes as "Fluffy," "Mittens," or "Smokey" innocently observes the tense crowd from a favorite comfy chair, scratching post, or sofa back. The species at large is the domestic cat. However, this recent surge in population within the last few decades and the effects of their predation have not gone unnoticed. Conservation programs, notably the controversial Trap-Neuter-Release, have been implemented in hopes of steadying and eventually reducing free-ranging cat populations. Whether they are effective in reducing the overall free-ranging cat population has yet to be concretely determined, but success has been found on a smaller scale.

Terminology: Which "Type" of Cat is Contributing to the Problem?

Primarily, it is important to distinguish to which type of "Fluffy" these striking data are referring. The broad species term of domestic cat (*Felis catus)* is comprised of two major categories based upon their exposure to an outdoor environment. There is also some variation in labeling these categories across studies, so the most common terminology will be used. The first

category, known as "indoor" cats, remain strictly inside, and do not participate in any type of hunting behavior that will impact an outdoor habitat (Feral cats…2013). Because of their lack of effect on local prey species and generally well-controlled reproduction, any further reference to "cats" does not include the strictly-indoor variety, unless otherwise noted. The second major category is referred to as "free-ranging" or "free-roaming" cats (Elizondo et al. 2016). And under the umbrella term of "free-ranging" are three sub-categories differentiated by their dependency level on humans, as well as their ownership situation. The first is "free-ranging pet" cats. They are owned felines, but have outdoor access to hunt. The second sub-category is "semi-feral" cats. These do not have an owner, but are partially dependent on humans who may leave out food or provide shelter. And finally, "feral" cats are those who are also unowned, but are completely independent from humans for survival (Elizondo et al. 2016). Because all cats that fall under the umbrella term of "free-ranging"—pets, semi-feral, and feral—have outdoor access, and thus an impact on their neighborhood environment and biodiversity, these are the primary focus of the to-be discussed population control programs, not indoor cats.

Negative Impacts of Rising Cat Populations on the Environment and Biodiversity

While the statistics concerning the impacts and population of free-ranging cats are noteworthy, it is important to compare the effects of cats on the species they coexist with relative to other invasive mammals' similar environmental impacts (Doherty et al. 2016; Feral cats…2013). This would establish cats as a true invasive species with a significant negative effect on biodiversity. In a metaanalysis by Doherty et al. (2016), the researchers determined the top seven most impactful invasive mammalian predators based on the risk they pose to threatened and extinct species, with free-ranging cats rising to the top of the list. Because domestic cats were originally bred in Western Asia, they are non-native to North America (Feral

cats…2013), and are already widely considered an invasive species due to their threat to native biodiversity, disease transmission, proliferation, and facilitation with other invasive species (Doherty et al. 2016). Doherty et al. (2016) attained their information on threatened and extinct species from the well-respected International Union for Conservation of Nature and Natural Resources' Red List (Red list 2017). Bird, mammal, and reptile species on the Red List had their top mammalian threats listed, and Doherty et al. (2016) reported on the top seven most frequently cited of these threats. The mammalian threat count that resulted was cats, rodents, dogs, pigs, small Indian mongoose, red fox and stoat making the top seven most impactful invasive mammals, with cats by far having the most overall significant impact on the three categories of measure—threatened/extinct bird, reptile, and mammal species (Doherty et al. 2016; Figure 1). Cats were directly linked to the extinction of 40 bird, 21 mammal, and 2 reptile species, or a staggering 26% of all modern extinctions (Doherty et al. 2016). And while the primary focus of my study will be the United States, the impacts of feral cats on endangered species in Australia are also important to note. No other continent has lost more extinct species since the 15th century than Australia, amounting to at least 23 (Frank et al. 2014). While not all of these losses can be associated with free-ranging cats, a recent assessment by the Australia Commonwealth Threat Abatement Plan associates 36 Australian mammals to be threatened by cats (Frank et al. 2014). And while populations are not as high as in the U.S.—fluctuating between 1.4 and 5.6 million depending on rainfall—free-ranging cats are now present on over 99.8% of the continent's land area (Legge et al. 2017). The threat to biodiversity is so severe that cat-free islands to serve as mammal refuges are being considered (Frank et al. 2014).

Cat predation on bird species could be considered a direct effect of rising cat populations. However, there are other hypotheses stating that simply the increased presence of cats in an area

is indirectly contributing to the decline of birds. Bonnington et al. (2013) considers this a "fear effect," which is a type of sub-lethal effect. Sub-lethal effects, in this case brought on by the fear and stress of predation risk due to the stealthy hunting behaviors of free-ranging cats, alter prey behaviors such as foraging patterns and habitat changes (Beckerman et al. 2007). These behavior changes can then lead to deviations from normal life-history traits such as adult and juvenile survival or clutch number (Beckerman et al. 2007). The mathematical model of Beckerman et al. (2007) used approximate ratios of cat to individuals of specific bird species to determine if fear effects would have a substantial enough impact to contribute to the bird decline ornithologists have been observing. After testing multiple hypothetical reductions in fecundity (0, 1, 2, 3, 6, & 9%), the model demonstrated that given the substantial rise in cat population since the 1970s, even a weak sub-lethal effect could cause a significant reduction in bird population (Beckerman et al. 2007).

Not only are cats skillful hunters capable of having both direct and indirect impacts on prey species, their natural hunting tendencies contribute to the nature of their invasiveness. Adamec (1976) determined that even when cats have been deprived of food for 48 hours, they would often prefer to hunt rather than taking advantage of an available meal. Researches presented the hungry cats with commercial meats, then, mid-meal, a live mouse was released. Results showed that five out of six cats would stop eating the provided meat and preferentially hunt, indicating the strong natural instinct of this species to kill prey when given the opportunity (Adamec 1976). In addition to their tendency to hunt rather than scavenge, cats have also been shown to hunt even when well-fed (Adamec 1976; Kitts-Morgan 2015). Given their overall predisposition to hunting, it is testament to the constant threat any nearby prey species faces with increased cat abundance. And to add to the intensity of their effects, not only are they constantly

hunting, but they are an extremely prolific species, that if unchecked, can rapidly populate an area at the detriment of any local rodent or bird populations. Cats can become sexually mature at only six months of age, and one female can have between two to three litters per year (Root et al. 1995). With each litter size rearing between two and four kittens, there is a possibility of up to twelve new cats being added to a population every year, per female (Root et al. 1995). This deadly combination now puts the free-ranging cat opening statistics into context, making it a very real issue.

Risk Factors for Humans

With this almost unbridled population growth, these cats are inevitably encountering more and more people, posing a new set of threats not only to any local prey species, but to their new human neighbors as well. The least invasive of these issues are often just increased noise, mess, and smell where cat colonies occur. However, they can be as serious as transmission of zoonotic diseases—those with the capability of passing from animal to human (Appleby et al. 2014). The most serious disease threat is the rabies virus. Fortunately, due to the mass vaccination of dogs beginning in the 1940s, there are only a handful of rabies deaths in U.S. yearly (Roebling 2014). However, free-roaming cats make for vectors of the disease because of their increasing potential contact with racoons—a reservoir for the disease—as cat abundance in the U.S. is higher than ever (Roebling 2014). And because a person is more likely to approach a free-ranging cat rather than a racoon, it makes the potential for the disease spread even greater (Roebling 2014). If a person believes they might have been exposed, they are strongly urged to begin the potential exposure prophylaxis (PEP) vaccine regimen (Roebling 2014). And while approximately 38,000 people receive the PEP vaccines every year, cat bites as a source of the potential exposure make up about 16% of cases (Christian 2009).

Importantly, in areas where there is a significant free-ranging cat problem, this number is elevated. For example, the state of New York attributed 23% of all PEP vaccination series to free-ranging cat bites or cat saliva exposure to the victim's mucous membranes—more than any other exposure source (Roebling 2014). And in a study conducted in Montgomery Country, Virginia—a country with a well-established free-ranging cat population epidemic—63% of PEP vaccines were due to free-ranging cat bites out of the 640 total cases (Hensley 1998; Roebling 2014). This highlights that free-ranging cats have a significant amount of contact with humans. While there was only one incidence of the animal testing positive for rabies, it indicates that the risk, while minimal, is most definitely present, and is likely to only increase as local cat populations grow (Hensley 1998).

The other significant zoonotic parasite risk is for transmittance of *Toxoplasma gondii*, for which cats are the primary host (Feral cats…2013). Most cats obtain the parasite by eating an infected rodent or small mammal, and then it is transmitted through the cat's feces. Not washing one's hands thoroughly after cleaning a free-ranging cat's litter box or any soil exposure from gardening in areas where cats may eliminate is the primary mode of cat-to-human transmittance (Parasites…2015). While ocular and neurological symptoms can occur, the most common are simply flu-like symptoms. However, it does pose a significant threat to pregnant women. If the mother becomes infected with toxoplasmosis during pregnancy, the infection can be passed onto the unborn fetus, potentially causing ocular and neurologic issues similar to adults, but can be as serious as a miscarriage (Parasites…2015). Dabritz et al. (2010) suggests that within the last 25 years, there has been a major increase in the number of cats in the U.S., which directly correlates to elevated instances of toxoplasmosis in humans. This cat population control issue has shown to be a significant public health issue, as well as an environmental issue.

Negative Impacts of Increasing Populations to the Cats Themselves

In addition to the disease risk factors cats pose to humans, especially as both cat and human populations rise, the increased cat-to-cat exposure can also put the cats themselves at more of a disease transmittance risk (Dombrosky and Wolverton 2014). The two major viruses are feline immunodeficiency virus (FIV) and feline leukemia virus (FELV). FIV, similar to HIV in humans, causes a depressed immune response, leaving cats extremely vulnerable to diseases it may encounter in its outside environment (Spada et al. 2016). It can only be spread through infected blood, which for free-ranging cats is commonly a bite wound. With cats being fairly territorial and the population increase promoting greater cat contact and confrontations, this disease could also be on the rise (Spada et al. 2016). Similarly, FELV is immunosuppressive virus, but is more contagious than FIV. It can cause anemia as well as leukemia, and can be spread through saliva (Spada et al. 2016). Infection can be attributed to anything from mutual grooming, nose-to-nose contact, and even a shared food or water dish (Spada et al. 2016). Free-ranging cats reside in social structures called colonies, making the likelihood of transmission even greater because of their repeated contact with many other cats that will only get exacerbated as abundance climbs (Crowell-Davis et al. 2004; Spada et al. 2016). This obviously is not limited to feral or semi-feral cats, as a brief encounter for a free-ranging pet cat with any infected individual could be enough for FELV disease transmission (Spada et al. 2016).

A Potential Method to Limiting Populations: Trap-Neuter-Release

Because of these major effects caused by the expanding cat population, there has been a call to implement programs intended to slow and eventually stabilize feral and semi-feral cat numbers. Two methods most commonly compared are called Trap-Neuter-Release/Trap-Neuter-Return (TNR) programs, or Trap-Euthanize (TE) programs. For ethical reasons, the strategy has

shifted more towards the former, but there is still a substantial level of controversy over whether TNR is still ethical (Burns and Paterson 2014; Dombrosky and Wolverton 2014; Downes et al. 2015; Jessup 2004; Longcore et al. 2009). However, an equally important question is if TNR programs are truly effective, and are worth the time, money, and services running one requires. TNR programs have been implemented in Europe since the 1970s, and have become more prevalent in the U.S. within the last 20 years (Nutter 2004). As the name suggests, unowned cats without any identification collars are often trapped using baited metal cages and transported to a veterinary facility where the cat is neutered (Appleby et al. 2014). Cats are not typically scanned for a microchip until the cat is anesthetized for safety concerns (L. Hockler, Broadway Feral Friends program, 2017 email interview).

Most clinics will at least vaccinate the felines against rabies, while others may include a FIV and FELV test, as well as testing and/or treatment for intestinal parasites (Appleby et al. 2014). Before the cat can be returned to its capture site, while still under anesthesia, the left ear is "tipped" (Trap-neuter-return (TNR) 2017). By removing approximately one centimeter of the ear tip, it provides a visual and universal designation that the particular cat has been neutered, and can be immediately released if recaptured in the future. Some studies rely on this identification technique to measure the general effectiveness of TNR programs in an area, with the intention of trapping more ear-tipped cats and less of those still requiring neutering the longer the program is in place (Hughes et al. 2002; Natoli et al. 2004). However, ideally, TNR programs would also reduce the many of the concerns previously outlined. Neutered males are less likely to spray or vocalize, cutting down on the potentially nuisance behaviors like the smell or noise (Appleby et al. 2014; L. Hockler, Broadway Feral Friends program, 2017 email

interview). They are often less aggressive, resulting in less fights between cats and therefore less puncture wounds—reducing transmission of FIV and FELV (Appleby et al. 2014).

Additionally, there is evidence that weight gain is another positive effect of the surgery. Scott et al. (2002) recorded the body weight (BW), body condition score (BCS) and size of the falciform fat pad, or the typical spot of weight gain on a cat, on 63 semi-feral and feral cats brought in for neutering via a TNR program. Researchers observed that while the cats were not emaciated upon capture, they were slightly leaner. One year later, locals were asked to recapture as many of the cats again for remeasurement, successfully trapping 14 of the original 63. Thirteen of the 14 subjects displayed significant increases in the three evaluating measures of fat pad depth, BW, and BCS, suggesting the neutering procedure helps with overall weight gain (Scott et al. 2002). However, perhaps the most obvious effect of the surgery, but definitely the most critically important, is that a portion of colony is no longer viable for reproduction.

Despite these positives, some argue there are negative welfare aspects to the TNR method. The ordeal of trapping, transportation, surgery, and re-release can be extremely stressful for cats, especially those not accustomed to physical interaction with humans (Burns and Paterson 2014). For programs that also vaccinate the cats against rabies, if those cats are never recaptured, that may be the only rabies vaccine they receive in their lifetime, which will be ineffective within a few years (Roebling 2014). Finally, to be discussed in both Natoli et al. (2004) and Castillo et al. (2003), the introduction of a TNR program within an area often leads to an increase of illegal, often intact, cat dumping by locals. Not only is this detrimental for the introduced cats, but TNR does not prevent against immigration (Burns and Paterson 2014). These new cats have the potential to render the program ineffective.

From an economic standpoint, a study conducted a by Nutter et al. (2004) attempted to estimate the associated costs with implementing a TNR program on nine, relatively small cat colonies. The researchers trapped the cats one colony at a time until either 90% of the colony had been collected or all but one cat in the entire colony remained untrapped (Nutter et al. 2004). Because these were of the semi-feral variety with colonies comprising of a fairly limited number of individuals, locals who were used to seeing and feeding the cats—citizens often called "colony caregivers"—were depended upon when deciding the appropriate 'stopping point' parameters stated above were reached (Nutter et al. 2004). Nutter et al. (2004) concluded that it would cost approximately $37.39± 19.66 to trap their mean number of cats per colony, which was 12.8. This cost included the mackerel necessary to bait the traps, as well as paying a worker to reset traps and collect any trapped cats on both a daily and nightly basis, in which he or she was paid the rate that county animal control trap setters would have received, $7.30/hour (Nutter et al. 2004). The startup costs of the traps, however, each within the $60-70 range, were not included in this final number (Nutter et al. 2004). Also not included in this estimated cost was for the surgery itself, which Lohr et al. (2012) estimates $40 per neuter and $50 per spay, and can sometimes be subsidized by state government. Monetary donations to local programs also commonly fund the necessary costs (Nutter et al. 2004). In this regard, TNR is a fairly cost-effective strategy, but this may only be the case for such small colonies and programs. For larger colonies, other strategies besides relying on locals to identify cats may be necessary, as well as requiring an increase in labor costs because of the anticipated additional nights needed to trap the larger population. Additionally, this was a relatively brief study, with data collection taking place over a few months. With a larger TNR program, such as the one studied by Natoli et al. (2006) in Rome, Italy, taking place over the course of a decade and fixed over 8,000 cats would

be a much larger financial investment. While Nutter et al. (2004) and Lohr et al. (2012) could be used as a model to anticipate costs, it can also highlight where larger programs could be cost-prohibitive.

Questioning the Effectiveness and Ethicality of TNR Programs

Because of the complexity of the potential benefits and detriments associated with TNR programs, there is a great deal of controversy over whether they are worthwhile, given the almost unfathomable size of the free-ranging cat population and the argued effects of TNR programs being relatively insignificant. What one's definition of effectiveness is for a TNR program depends on his or her ultimate goal. A feral cat advocate will have different goals than a conservationist (Longcore et al. 2009). A conservationist is more inclined to be concerned about the drastic and negative effects cats have on native prey species, so his or her goal would be to remove this threat. Because TNR programs only reduce the number of future predators, neutered cats today still prey upon threatened bird and mammal species, thus not directly achieving their "goal" (Appleby et al. 2014). Because of this, TE programs are the only immediate and permanent elimination of the predator, and thus the method most likely supported by conservationists. TNR advocates, contrastingly, would have the primary goal of ensuring TNR programs are actually stabilizing or reducing population size, thus shifting the focus from the welfare of the prey species to that of the cats (Appleby et al. 2014). To add in further complexity, some TE supporters vouch for the well-being of the re-released cats and call TNR programs 'subsidized abandonment' (Jessup 2004). It is argued that these cats do not receive the regular veterinary care they require, often suffering from chronic ear mites, intestinal parasites, or upper-respiratory issues, and living significantly shorter lives—two years—compared to their house-bound counterparts with an average of ten years (Jessup 2004). These values are debated

though, with one study reporting a mean lifespan of over seven years for free-roaming cats and no significant difference in body weights between the outdoor cats and pets (Levy et al. 2003). All parties' views of managing the population highlights the complexity of this issue.

Alley Cat Allies, one of America's largest TNR-advocacy organizations, aims to help educate the public about the benefits of TNR, encourages laypeople to become involved to start their own neighborhood TNR programs, as well as helps to provide networks of veterinarians and shelters that perform the low-cost surgeries (Trap-neuter-return (TNR) 2017). The organization highlights a handful of studies that demonstrate TNR programs meeting the overarching goal of either population reduction or stabilization. However, it is questioned whether these acclaimed studies were truly effective or even a typical model of TNR programs around the country. In the first of which, Hughes et al. (2002) reported on a TNR program implemented on Texas A&M University campus by their College of Veterinary Medicine senior students and professors. Over the course of two years, approximately 30 traps were laid out for four to six nights every month, where any cats caught the previous night were brought in for vaccinations, neutering, and ear tipping. They were successful in catching 158 cats total between the two years of collection, and determined the success of the program based on if significantly less cats were caught in Year 1 of the study compared to Year 2 (Hughes et al. 2002; Figure 2). Year 1 resulted in 123 of the 158 totals cats caught, while in Year 2, students only trapped 35 individuals (Hughes et al. 2002). There were also instances of 17 re-caught adults, which were re-weighed and compared to weights at the time of their initial capture for surgery. Their differences in weights between the two captures was significant ($p=0.01$), and paralleled the conclusion of Scott et al. (2002) with a median increase in weight of 0.3 kg (Hughes et al. 2002).

By the standards of Hughes et al. (2002), the decrease in new cats captured from Year 1 to Year 2 alluded to a decline in the campus's free-ranging cat population. They had even reported a decline in the number of cat nuisance complaints between the two years, but no actual values, nor significance were mentioned (Hughes et al. 2002). However, it is important to note that while this was considered a TNR program, it more appropriately fits the model of what is considered a TNR+ program (Appleby et al. 2014). Kittens that were captured as well as any tame adults were placed into adoption instead of being re-released. This amounted to a total of 17 kittens and 15 adults, for a total of 32 cats no longer available for recapture (Hughes et al. 2002). Some criticize that because of this additional component of Texas A&M's TNR program, the results are atypical (Appleby et al. 2014). Granted, it would not interfere with the data Hughes et al. (2002) used to make their reduction in population conclusion, as these adopted out individuals would have been tabulated in their appropriate year's data, and any re-catch would have been marked as such, not as a new individual, which was the critical aspect of the data per the researchers. However, not all TNR programs have the luxury of putting some of their friendlier trapped cats into adoption programs.

Another study praised by Alley Cat Allies was conducted by Natoli et al. (2006) in Rome, Italy. The Veterinary Public Services (VPS) offers the neutering procedure for no charge for TNR participants. Over 8,000 cats were trapped and neutered within this timeframe, and it generated very encouraging data. Before the neutering campaign, the number of cats in each colony was between four and 50 (Natoli et al. 2006). Whereas after the data collection was complete, colonies ranged from two to 40 individuals (Natoli et al. 2006). Two years into the program, there was already an average of 16% colony reduction size, while after six years, researchers observed a 32% reduction (Natoli et al 2006).

However, an important component of TNR is public education. All colonies were reported and tabulated by the VPS, and as the program became more well-known within the city, it was concluded that more and more people abandoned their cats thinking they would be fixed by VPS and fed by colony caregivers (Natoli et al 2006). While the average number of individuals in a colony decreased, the number of newly registered colonies skyrocketed. In 1991, there were only 76 registered, while by the conclusion of the data collection in 2000, there were 965 colonies registered (Natoli et al. 2006). This shows that without the proper public education about the importance of responsible pet ownership and the true purposes and intentions of TNR, success rates can be hindered. This was even the author's concluding remarks, saying that without the proper messages being disseminated to the masses, "[TNR] efforts are a waste of money, time, and energy" (Natoli et al. 2006).

On the other hand, a major supporter of TE is the American Bird Conservancy. They believe their most convincing arguments against TNR programs is that the effects are insignificant against the backdrop of the overwhelming cat population (Cats and birds 2017). Anderson et al. (2004) use a matrix population model to test even the most rigorous TNR programs against TE. Because each program affects a different vital rate—TNR with reproduction and TE with survival—both rates were able to be modified to test each type of program implementation (Andersen et al. 2004). Results showed that even on fecundity's most extreme manipulation, a 75% reduction via TNR programs still yielded rate of increase of 1.08 (Andersen et al. 2004). This implies that an ongoing neutering of 75% of the cat population would still not be efficient to reduce the population. In contrast, a 50% reduction in survival yielded a rate of increase of less than one, meaning the population must be halved every year in order to see a decrease (Andersen et al. 2004). In nearly all of the different survival and

fecundity scenarios, rate of change was more sensitive to survival augmentation than fecundity augmentation, suggesting that TE is more efficient of a program because less cats need to be caught to achieve a reduction in population (Andersen et al. 2004).

In a final study promoted by the American Bird Conservancy, Castillo et al. (2003) studied two cat colonies in public parks in Florida. Prior to the implementation of the program, Castillo and fellow researchers spent months observing, photographing, and recording characteristics about the cats in each colony, eventually compiling a thorough photo album of each cat (Castillo et al. 2003). Following the TNR program, the researchers engaged in similar capture-recapture techniques by once again using their cameras, not cages, to identify an anticipated reduction in the number of new cats, as well as cats overall. However, during each session, Castillo et al. (2003) witnessed at least one new cat in each of the parks, suggesting an illegal dumping situation similar to Natoli et al. (2006) was occurring (Andersen et al. 2003; Figure 3a&b). The constant introduction of intact cats to populations resulted in a growth in abundance in both park locations, and thus, an ineffective example of TNR highlighting the necessity to encourage more responsible pet owner practices (Andersen et al. 2003)

Proposed Study

Castillo et al. (2003) and Natoli et al. (2006) highlighted that any potential progress made by a TNR program can be undermined by abandonment from misinformed locals. There is a misconception that if a program is implemented in a neighborhood, all free-roaming cats will be fed, fixed, and vaccinated (Jessup 2004). Therefore, residents in those areas who no longer wish to take care of their cat see this as a beneficial situation for both themselves, as well as the cats who will now supposedly receive perhaps even better care than while they were owned pets. Residents often have the opportunity to relinquish ownership at local shelters whether there is a

local TNR program or not, but are either unaware of this option, too embarrassed to pursue it, or do not want to pay the shelter's fee often associated with the decision (Jessup 2004). This now illegal abandonment by the former owners is the main source of immigration of new free-roaming cats into an area (Jessup 2004). As predicted by many mathematical models, only when immigration is at 0% is when the TNR or TE program can actually have a predicable decrease to the population (Andersen et al. 2004; Schmidt et al. 2009). Even with just a 1% immigration rate applied to a model of the 16,700 free-ranging cats on the island of O'ahu, Hawaii, the population will never drop to below 2,000 individuals even after 30 years of intense TNR implementation (Lohr et al. 2012; Figure 4).

Due to free-ranging cat social structure, new cats are rarely immediately welcomed into a colony (Crowell-Davis et al. 2004). It is not uncommon for the last remaining cat of a colony that has been depleted over time by TNR to go over two years attempting to become accepted within another colony or to begin another (Crowell-Davis et al. 2004). This tendency of recently immigrated cats to form new colonies rather than enlarging established ones substantiates the dramatic increase in colony number from 76 to 965 reported by Natoli et al. (2006) over the course of the nine-year study. It is also hypothesized that the longer the TNR program ran, the more publicity it received, thereby exacerbating rates of abandonment (Levy et al. 2003; Schmidt et al. 2006). Therefore, it is critical that owners know the true purpose of a TNR program is not to offer an alternative life for any unwanted pet cats, but rather to control the populations of those already free-ranging and aptly adjusted for the types of outdoor challenges perhaps never previously faced by pet cats.

It has been suggested by Levy et al. (2003) and Schmidt et al. (2006) that making local citizens more aware of the true purpose of a TNR program could help to reduce abandonment,

and therefore, immigration. However, no study has ever been conducted whether or not this is an effective and worthwhile strategy prior to a TNR program being implemented within a neighborhood. However, on a local level, even minimal public intervention has shown to have positive effects on the overall reduction of cats requiring neutering. Lindsay Hooker, co-founder of Broadway Feral Friends of Rock Island, Illinois, spoke of efforts to make educational posts via social media, and teaching donors about TNR so they can pass the proper education on, too (L. Hockler, Broadway Feral Friends program, 2017 email interview). Beginning in June 2014, their first six months resulted in 33 cats trapped and assisted (L. Hockler, Broadway Feral Friends program, 2017 email interview). This was followed by 32 cats in all of 2015, and only 15 in all of 2016 (L. Hockler, Broadway Feral Friends program, 2017 email interview). Therefore, this proposed study is meant to determine if a more rigorous public awareness initiative informing citizens on responsible pet ownership, the accurate goals of a TNR program, and alternative manners to relinquish ownership of unwanted cats that will not contribute to abandonment will affect the success of a program and lower immigration.

One city with a population of approximately 40,000—Rock Island, Illinois as an example—with a free-ranging cat issue will be the site of the experiment. This human population requirement is due to one of the cat population measuring parameters being used—trail cameras with the mark-resight method—has only been recently applied to more urban settings, so as not to stress this method beyond what has already been shown to be successful (Elizondo et al. 2016). The city will then be broken up into 10 neighborhoods of comparable area, human population, socio-economic status, and urban development, all of which are factors that have been related to free-ranging cat population densities (Finkler et al. 2011; Legge et al. 2017; Schmidt et al. 2006). None of the sites will formerly have a local TNR program

established. Five of the 10 towns will be randomly selected to undergo a public awareness campaign on the local free-ranging cat issue, the importance of responsible cat ownership, proper relinquishing actions if necessary, and the misconceptions of what a TNR program does and its true purpose. This education will be multi-faceted, using awareness campaign strategies of mailed letters, informational doorhangers, and a Q&A session held by a local TNR organizer and veterinarian for residents who wish to learn more. There will be a URL on all distributed literature for an informational website, designed to go into further depth on the important topics listed. The phone number to report a colony and listings of local shelters willing to take owner-surrendered cats will be listed. There will also be an email address for anyone who wishes to communicate or ask questions via this method. The remaining five control towns will receive mailers and doorhangers, but only with the phone number and/or email address necessary to report a colony, with none of the in-person or thorough educational information. This is necessary because colony reports were a critical parameter in Natoli et al. (2006) in measuring immigration.

All 10 towns will attempt to estimate the initial free-ranging cat population numbers prior to TNR program implementation. This will be done using the trail-camera method described in Elizondo et al. (2016), as it has shown to be fairly accurate in a suburban-like area of similar cat and human population densities. The same mark-resight tabulating process imputed into the Poisson log-normal mark-resight mathematical model will be used to generate the cat populations in both areas (Elizondo et al. 2016). Colony caregivers would also be encouraged to report colonies to the program to monitor both the number of colonies and populations within each one over the course of the study. Each colony report will be investigated by the TNR program so as not to double-report colonies.

In addition, a common practice by TNR programs to monitor progress is simply keeping track of the number of trapped cats without the ear-tip indicator over time once the program is implemented (Hughes et al. 2002; Natoli et al. 2006). All three strategies will be used for the most comprehensive picture of the free-ranging cat population within both neighborhoods over time. After two months of pre-program population data collection (Castillo et al. 2003; Elizondo et al. 2016), each site will then initiate their programs. Using the pre-program population estimates, 57% of the cat populations within each neighborhood will be attempted to be caught and neutered, which is the minimum portion of the population needed for a reduction per the mathematical model of McCarthy et al. (2013). The programs will run for a minimum of three years, as has been shown through mathematical models that TNR program effects may not be fully reflected within the first two years of data (Frank 2004; Gunther et al. 2002; Natoli et al. 2006). However, significant impacts by programs have been observed even within this initial window (L. Hockler, Broadway Feral Friends program, 2017 email interview; Natoli et al. 2006).

At the culmination of the TNR program period, the same trail camera sight-resight method will be used to obtain post-program population estimates to determine a significant decrease in population size, but also any increase of photos containing cats with their ears tipped. Similarly, the number ear-tipped cats physically trapped during the TNR program compared to those trapped still needing neutering will be plotted on a monthly basis throughout the three-year study, comparing both neighborhoods. In addition, the number of additional colonies reported since the beginning of each program will also be tabulated and compared to the pre-program data. Each of the three measurement parameters will be analyzed using a repeated-measures ANOVA to determine if the TNR programs had a significant effect on cat population reduction overall. If significant, a post-hoc Tukey's HSD test will be implemented to determine the

relationships driving the significance, hopefully to reveal increased public awareness substantially impacting both cat population decline and immigration compared to control neighborhoods.

However, there are some limitations to this study. Elizondo et al. (2016) noted how while the trail camera identification system was effective and generated a confidence rating of over 95%, some solely black cats had no unique features to determine if a sighting was a 'mark' or a 'resight' (Figure 5 a&b). This may always present a problem, no matter the quality of trail camera used unless multiple cats happened to be captured within the same picture. In addition, the data collected for the number of colonies is very much dependent on the reporting of locals. It was considered successful in Natoli et al. (2006), which suggests that if the information is available to residents on how to report a new colony, they will do so. However, some neighborhoods may adopt the reporting practice with a different fervor than others.

The data will be analyzed to determine if increased public awareness can offset the immigration rates due to owner abandonment usually associated with the introduction of a TNR program into an area. If there is a significant difference between the two neighborhoods for overall population and colony numbers, it will suggest that the extra effort of educating the neighborhood the TNR program will be serving is a worthwhile investment. In addition, because the city was attempted to be divided into relatively homogeneous neighborhoods regarding socio-economic status, a comparison of neighborhoods could be done using the Tukey HSD post-hoc tests to determine which neighborhoods are the most affected by this intervention. As a follow-up, a survey could be conducted to determine which medium for disseminating information was the most impactful, which may also differ depending on the neighborhood.

In addition, there is a trend in the literature regarding managing cat populations that there is very little research available for estimates of cats within dense urban areas. While supposedly successful TNR programs have been implemented in major cities like Chicago, Washington D.C, Atlantic City, and the San Francisco Bay Area, populations are rarely estimated, and the frequency of recapture statistic, if used, is only applied to determine the effectiveness of that particular program, not the city as a whole (Trap-neuter-return…2015). Even Flockhart et al. (2016) points out this lack of information, saying there are no empirical studies done on cat population sizes for medium to large cities with human populations of 100,000 or more. This is important because cities have the potential to become a much more critical component of reducing cat populations than they already are. If the trail camera method suggests the same population trends as the counts taken concurrently with the TNR program, this could be further applied to more urban areas. The high density of people would provide a larger pool of volunteers to maintain both semi-feral cat colonies, as well as the logistics involved in a TNR program (Appleby et al. 2014). Not only that, but given the population of free-ranging cats has been shown to be correlated with human population density and urbanization, cities could be considered the "problem areas" of the cat overpopulation problem (Schmidt et al. 2006). Therefore, attaining accurate data from key urban locations could help better determine the progress of city TNR programs, and educational efforts can be even further concentrated within an area.

The overabundance of cats is not an inconsequential issue. They have already had an extreme impact on the environment and biodiversity, some of which is irreversible (Doherty et al. 2016). However, within the last few decades, there has been a surge in the number of TNR programs enacted with hopes of steadying and eventually reducing these populations (Trap-

neuter-return…2015). Despite the controversies associated with their effectiveness and ethicality, some TNR programs have shown to be successful in the sense of reducing the overall average of individuals within a colony (Castillo et al. 2013; Hughes and Slater 2012; Natoli et al 2016). But public education on the proper practices of being a responsible cat owner seems to be a major hindrance to the positive impacts these programs can have. At this point, no matter the success level, it is encouraging that there are many laypeople who are passionate about these programs, as only *they* will determine its outcome…because we all know the only thing Fluffy's concerned about is dinner time.

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Appendix

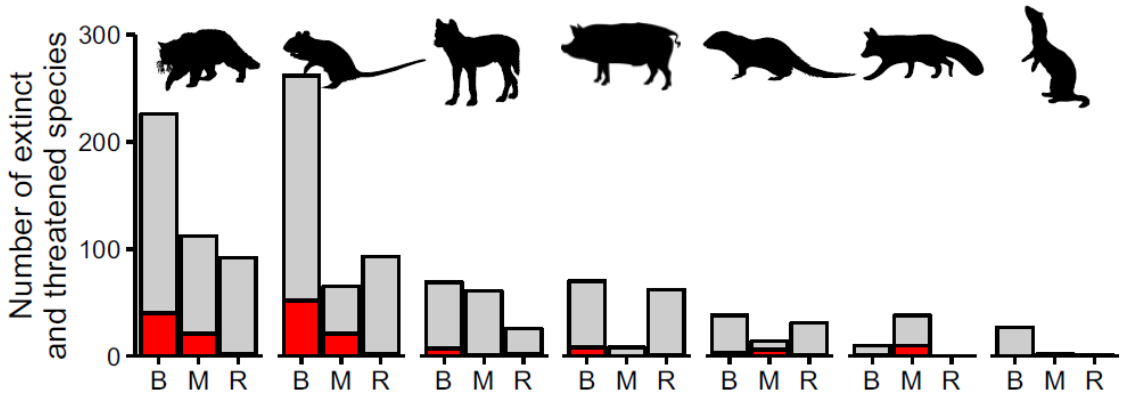

Figure 1. Gray bars indicate the value of threatened species impacted by the invasive animal outline above it, red bard indicate the value of extinct species. B=birds, M=mammals, R=reptiles. Free-ranging cats' impact is represented by the leftmost grouping of bars, and is considered to be the most detrimental to the Red Listed bird, mammal, and reptile species of all seven mammal species studied. Figure 2 from Doherty et al. (2016).

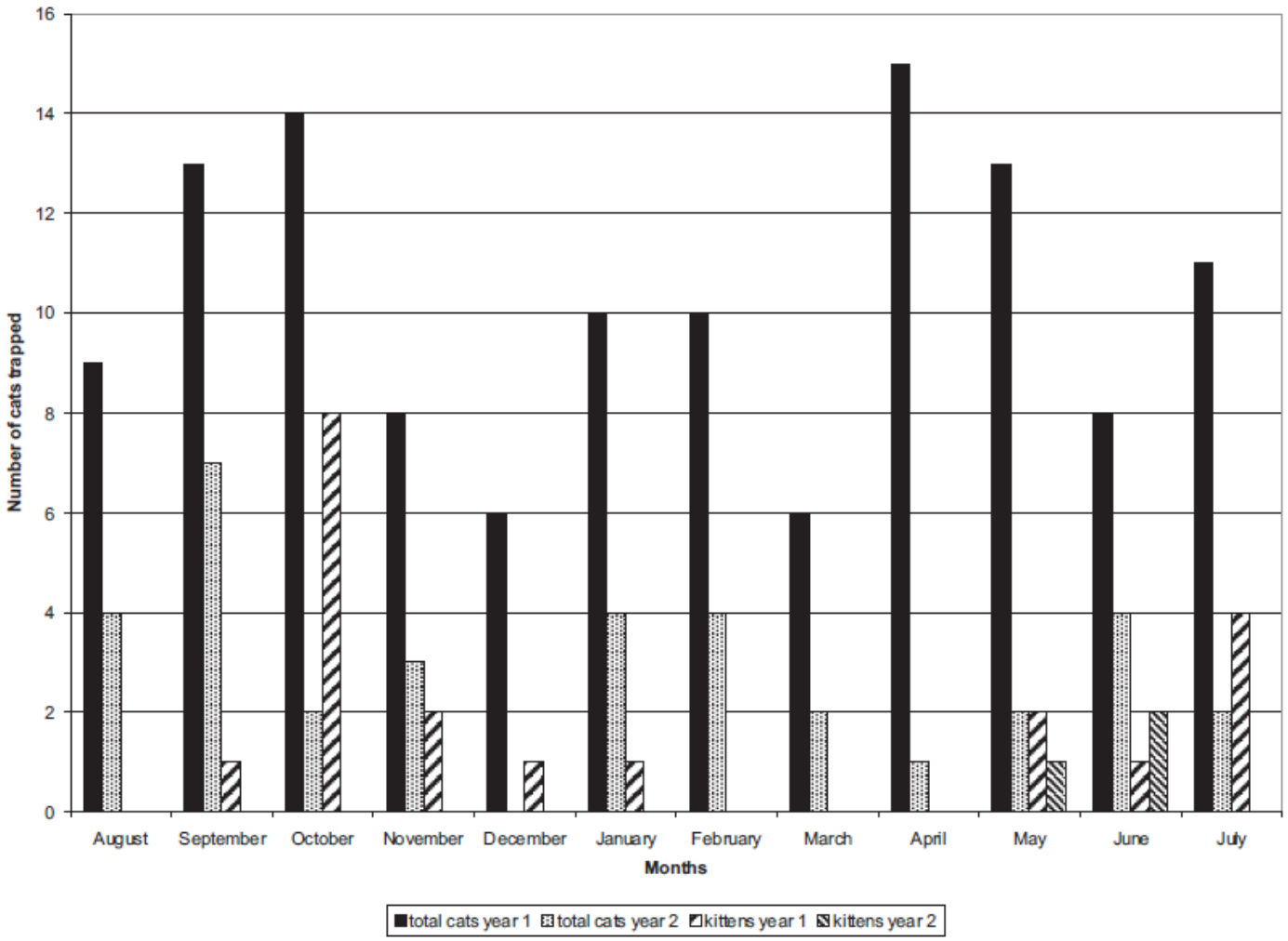

Figure 2. Total cats captured via Texas A&M University's campus TNR program by year. Every month's decline in cats captured from Year 1 to Year 2 researchers believed was evidence of a successful population reduction of free-ranging cats. Figure 1 from Hughes et al. (2002).

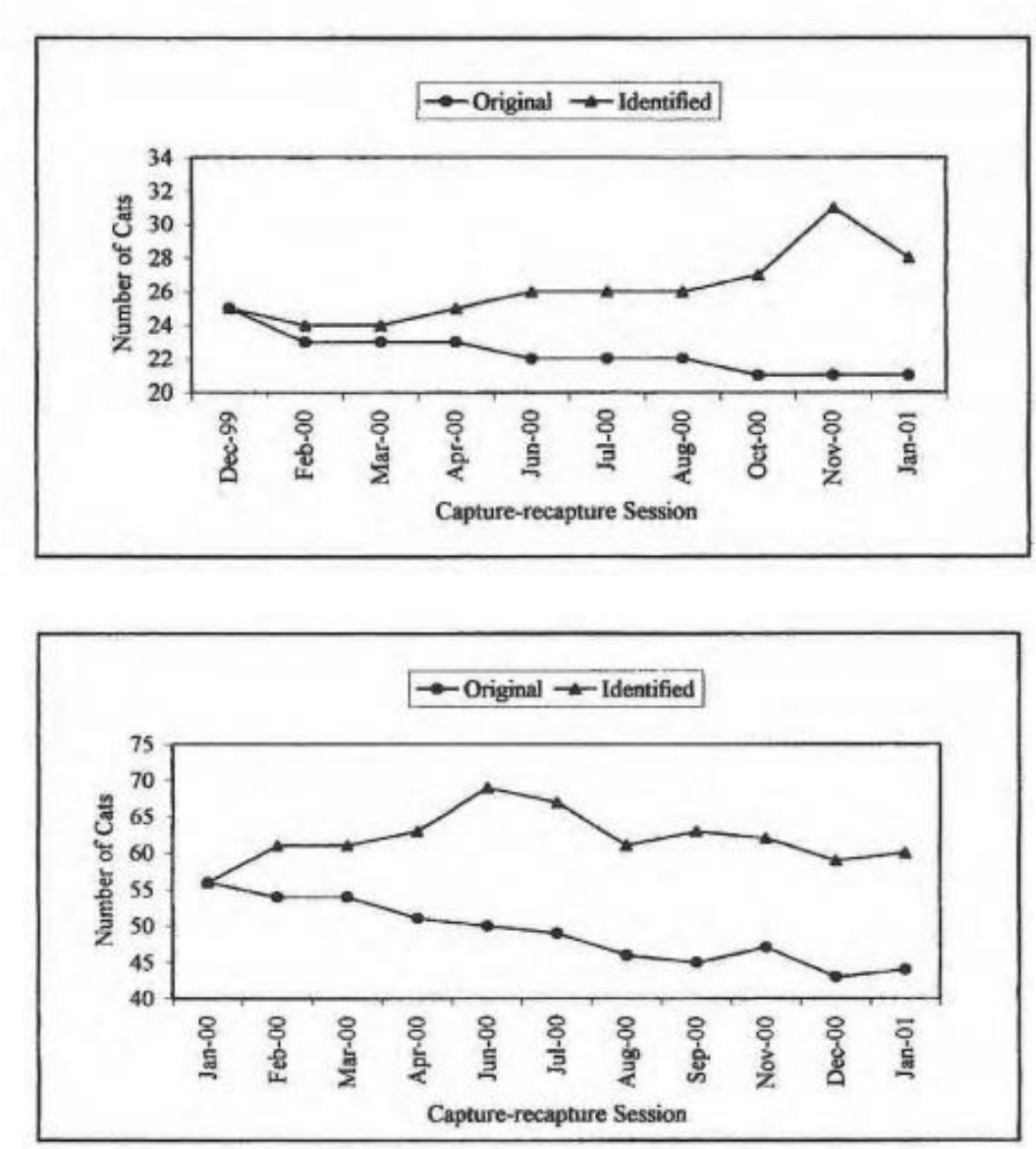

Figure 3a&b. Comparison of original cat colony observed prior to implementation of TNR program in A.D. Barnes Park ("original" line) to the total number of cats identified following the TNR program ("identified" line) (a) Comparison of original cat colony observed prior to implementation of TNR program in Crandon Marina Park to the total number of cats identified following the TNR program (b). This increase in new, previously unidentified cats was attributed to the illegal dumping of cats by irresponsible pet owners, thereby adding to the population of the colony. Figures 3 and 4 from Castillo et al (2003).

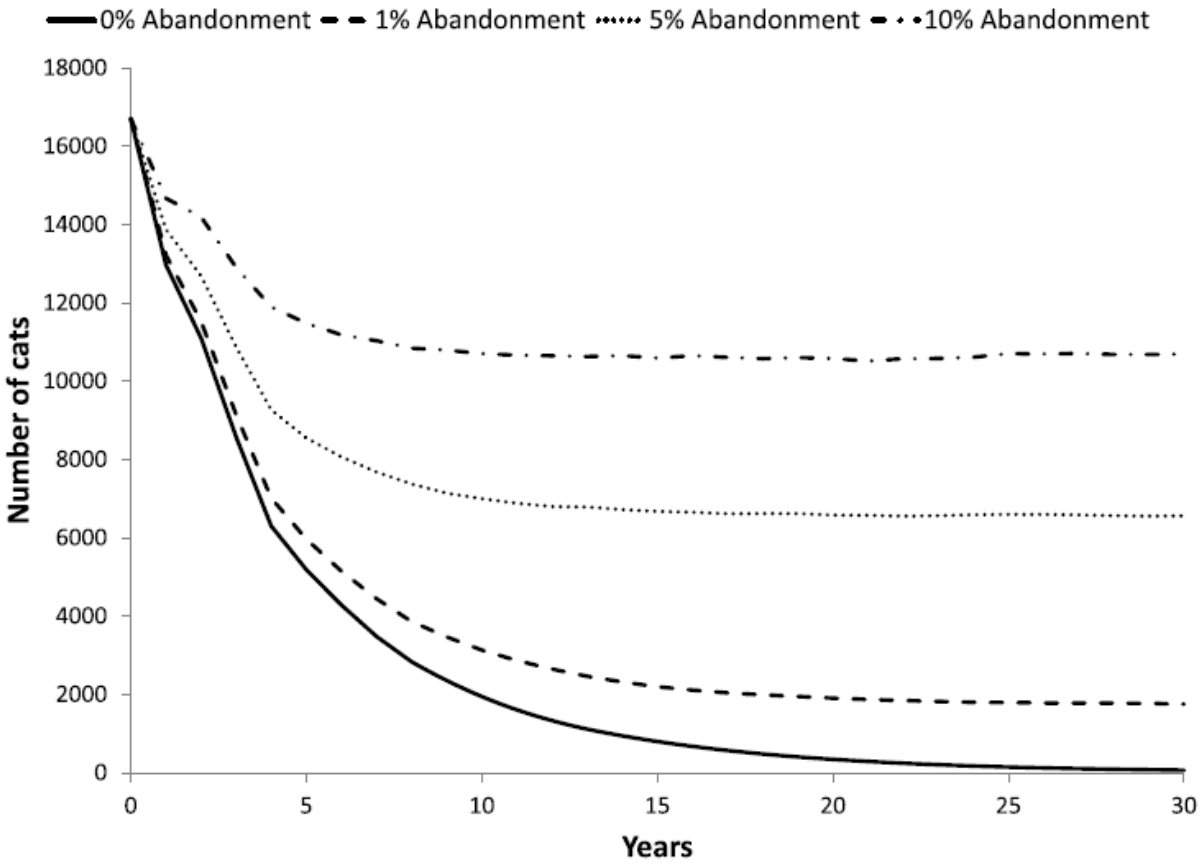

Figure 4. Mathematical model predicting the free-ranging cat population on the Hawaiian island of O'ahu. It demonstrates the drastic effect even 1% immigration (of the original population of 16,700 individuals) can have, disallowing the population to ever be eliminated even after 30 years of intense TNR intervention. Figure 2 from Lohr et al. (2012).

Figure 5 a&b. Examples of photographs from infrared trail cameras used for cat identification. These are different individuals at night (top) and during the day (bottom) to demonstrate the difficulty sometimes associated with distinguishing individuals. From Elizondo et al. (2016) supplementary information.